Shelf Convection in the Presence of Topography and Large-Scale Circulation: Some Numerical Experiements

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MODEL SPECIFICS

1) The convection model is **2.5D** (motion but no gradients in the y-direction) [Piacsek et al, 1997; Potts 1998].

2) The model uses the **VBM** (**V**irtual **B**oundary **T**echnique) [Goldstein et al, 1993; Potts, 1998] that represents topography with an external body force in the momentum equations. This enables the use of the very efficient Poisson solvers for pressure based on FFT's even in the presence of the irregular boundaries due to topography.

3) The model uses a Mellor-Yamada type **mixed layer model** as modified by Kantha and Clayson (1994).

4) **Spatial Resolution**:
- horizontal resolution dx = 25 m
- vertical resolution dz = 10 m

5) **Grid Size**: 641 x 65 (Figs. 1 and 2)
1200 x 150 (Fig 3)

6) **Domain Size:** 16 km x 650 m (Figs. 1 and 2)
120 km x 1500 m (Fig. 3)

7) **Forcing**:
- - Wind stress 3 dyne/cm**2 (Figs. 1-3)
- - Cooling: 300 watts/m**2 (al Figs.)
- Ice accretion rate: 1 cm/hour, with a net **brine deposit rate** of ~ 1.E-5 kg/m**2/sec.

For a discussion of observed and model-utilized cooling and brine-release rates in polynyas and leads, see also Muench et al (1995), Smith et al (1990) and Smith and Morison (1998).

8) **Open Boundaries**:
Closed at the coast (on the right)
Open at the left (open ocean)

9) **Initial Fields**: Levitus .25 deg annual mean climatology (Boyer and Levitus, 1997)

10) **Friction and Diffusion**: outside the mixed layer
A (hor) = 1.0 m**2/s
K (vert) = 0.25 m**2/s

For detailed discussion of spatial resolution, diffusivity values and grid sizes in convection problems, see Jones and Marshall (1993) and Kampf and Backhaus (1998); for a discussion of ice accretion and brine deposition rates, see the latter.

11) **Location of Polynya:**
Left edge: 9 km from shore
Right edge: 1 km from shore

Left Column: Temperature   Right Column: Streamlines

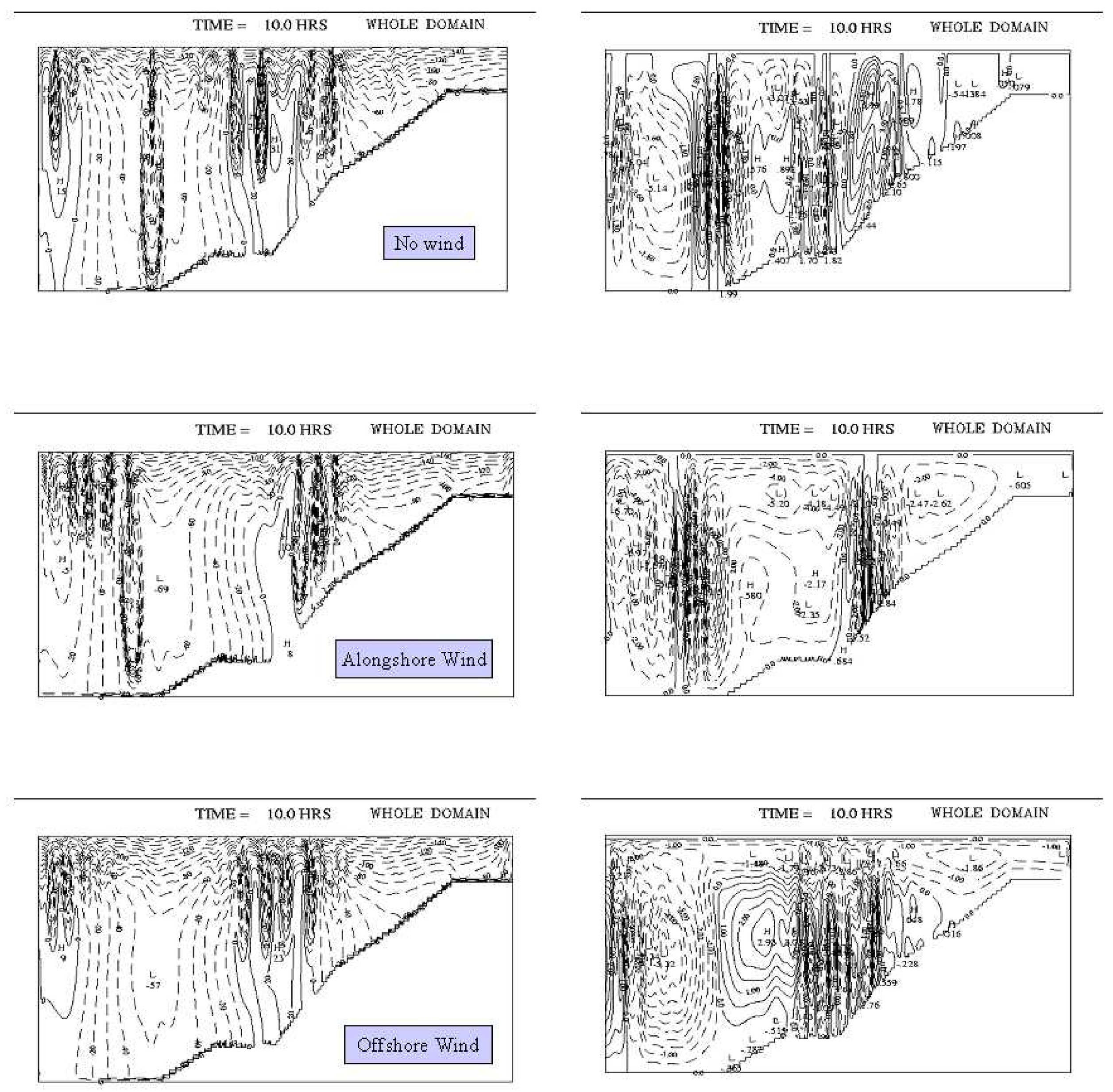

Fig. 1: Comparison of Wind Effects in the Basic Convection Experiment

Illustrates the interference of the wind-driven upwelling currents with the convective cell motions. The basic experiment applied a cooling of 300 watts/m² in a domain 16 km wide and 650m deep. The ambient fluid had constant temperature and salinity. The left boundary is open. The upwelling is associated with winds of 3 dynes/cm² , off-shore and along-shore currents (eastward in the southern hemisphere).

After an elapsed time of about 8 hours, convective plumes appear which reach the bottom in about 3 hours. Clearly, the stronger upwelling associated with the off-shore currents has a much greater effect, significantly retarding the evolution of the plumes and eliminating the appearance of the large plume visible near the left boundary in the no-wind and along-shore wind cases. Both wind cases change the location and spacing of the plumes.

Left Column: Case of Off-shore Winds   Right Column: Case of Alongshore Winds

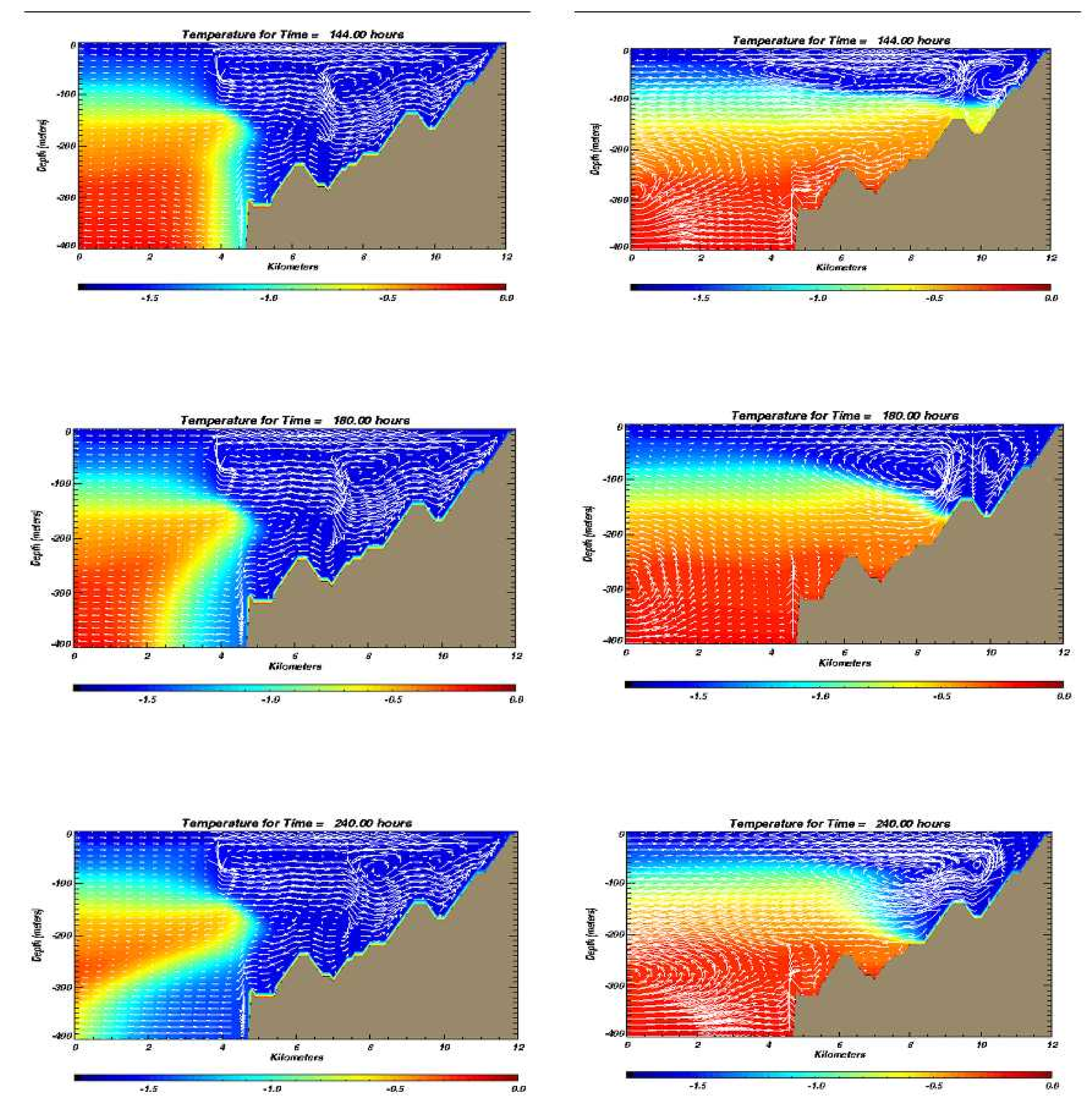

Fig. 2: Comparison of Wind Effects in the Simulation of a Coastal Polynya

Illustrates the realistic application of the convection model to a coastal polynya at high latitudes. The initial T,S profiles were made constant in latitude, with values corresponding to the mean of the region (143E, 65-68S) and were slightly adjusted to make the initial density profile stable. For each case of idealized wind forcings a constant wind of 3 dynes/cm² , either off-shore or easterly along-shore (both yielding an upwelling in the southern hemisphere).

The most striking differences between the two wind cases are: (a) the **formation of a strong front** under the open-sea (left) edge of the polynya **for the off-shore wind case only**; (b) the appearance of a strong downwelling plume near the center, ~ 2 km from shore in the along-shore case and ~ 5 km in the off-shore case; (c) the much greater depth of penetration of the the heavy plumes along the bottom in the off-shore case, and (d) the eventual **suppression of the upwelling currents in the along-shore case** after 10 days

After preliminary analysis, we attribute the greater penetration of the plumes in the off-shore case due to the location of the downward plumes over deeper waters, and to the presence of the front, which appears to funnel the recirculating motions of the convection downward and toward the shore.

SUMMARY

Some basic processes associated with buoyancy-driven convection in the presence of coastal upwelling/ downwelling currents are investigated. The studies are conducted in a 2.5D framework, with rotational effects and a turbulent surface mixed layer included. The representation of topography is done via the VBM (Virtual Boundary Method) that utilizes equivalent body forces in the momentum equations (Goldstein et al, 1993). As a result, the Poisson equation for pressure could be solved with a very efficient method based on FFT's.

Two classes of simulations were carried out: (1) some simplified process studies to gain an insight into the interference of wind-driven currents with the buoyant plume motions, and (2) some realistic applications to a coastal polynya at high latitudes. Each class of simulations was performed for two cases of idealized wind forcing: constant off-shore or constant along-shore. In addition, the basic process studies included a no-wind case for comparison.

In general, the basic experiments show a significant interference of the upwelling with the convective cell motions, changing their development time, spacing, and location of formation.

In the polynya experiments the convection appears to be partly forced, with additional vorticity generated by the flux discontinuities at the edges of the polynya. In addition, there seems to be a large difference between the off-shore and along-shore cases, including the formation of a strong front under the open-sea (left) edge of the polynya for the off-shore wind case, and the eventual suppression of the upwelling by the downward plumes in the along-shore case.

After preliminary analysis, we attribute the greater penetration of the plumes along the bottom in the off-shore case due to the location of the downward plumes over deeper waters, and to the presence of the front, which appears to funnel the recirculating motions of the convection downward and toward the shore.

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